

PHYSICAL SCIENCES AREA

Berkeley Lab HEP Program
Natalie Roe, Associate Lab Director for Physical Sciences
Snowmass Community Meeting, July 24, 2022



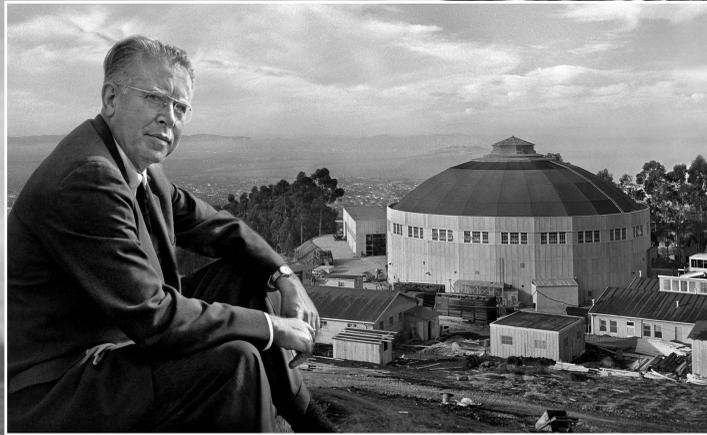
BERKELEY LAB



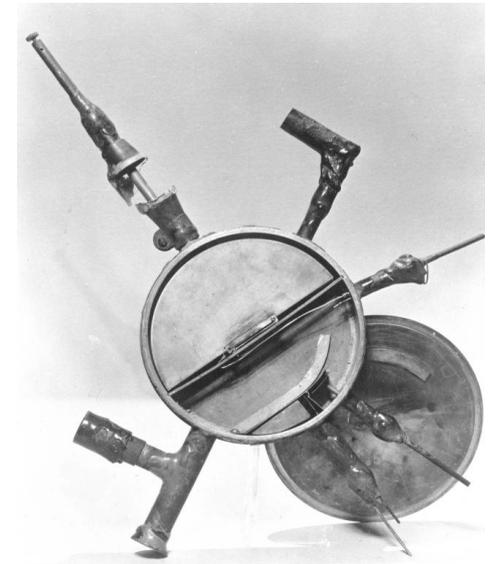
U.S. DEPARTMENT OF
ENERGY

Office of
Science

Berkeley Lab was founded in 1931 on two pillars: the cyclotron and team science



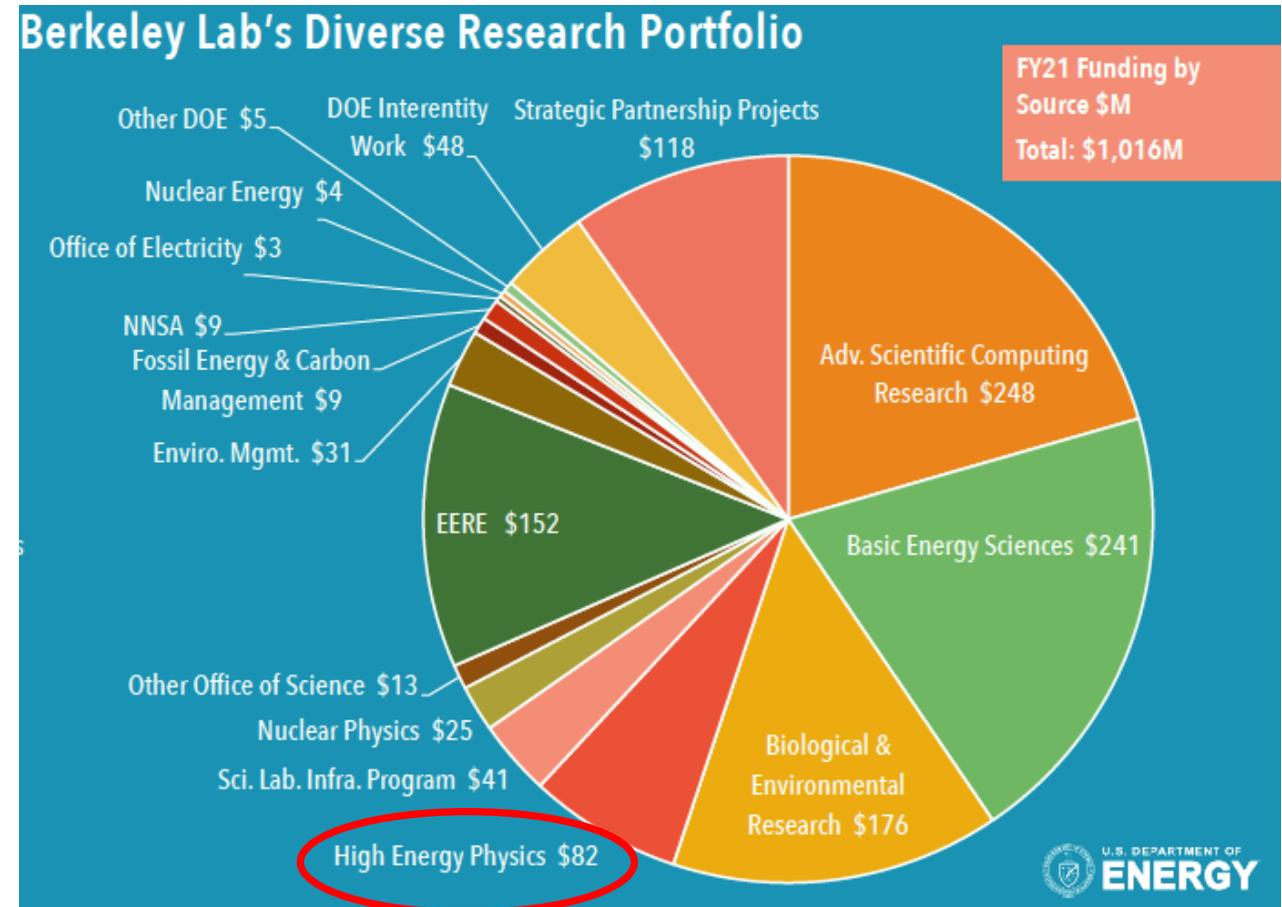
E. O. Lawrence and the
184" cyclotron (circa 1940).



The small seed from
which Big Science grew.

Today, Berkeley Lab is a diverse multipurpose DOE Lab

- Total FY21 funding \$1.016B, ~3700 FTE
- 5 Major User facilities with ~14K users
 - NERSC/ESNet
 - Advanced Light Source => ALS-U
 - Molecular Foundry
 - Joint Genome Institute
- The Berkeley HEP program benefits from multiple local connections
 - Engineering Division
 - Nuclear Science Division
 - Computing Sciences Area/NERSC
 - Materials Science Division/Molecular Foundry
 - Quantum System Accelerator (QSA)
 - UC Berkeley faculty and students, who are deeply embedded in our program
 - Synergies with ASCR, BES, FES, NP, NNSA...



Berkeley Lab HEP Program Overview

- Two Divisions
 - Physics and Accelerator Technology and Applied Physics
- Leading programs in
 - Energy Frontier – ATLAS group
 - Cosmic Frontier – Lead lab for DESI, LZ, CMB-S4
 - Superconducting Magnets – Lead lab for the US Magnet Development Program
 - Advanced Accelerators – BELLA center for laser plasma acceleration
- Tradition of Innovation in Accelerators, Detectors and Readout
 - TPC, Silicon vertex detectors and readout, Red-sensitive CCDs, Skipper CCDs, LArPix (DUNE), Quantised Quest program in QIS sensors and Qbit readout, Accelerator sources and control systems, Muon cooling, High power lasers...
- Cross-cutting AI/ML group and QuantISed program in QIS
- Home of the Particle Data Group



Physics Division
Nathalie Palanque-Delabrouille

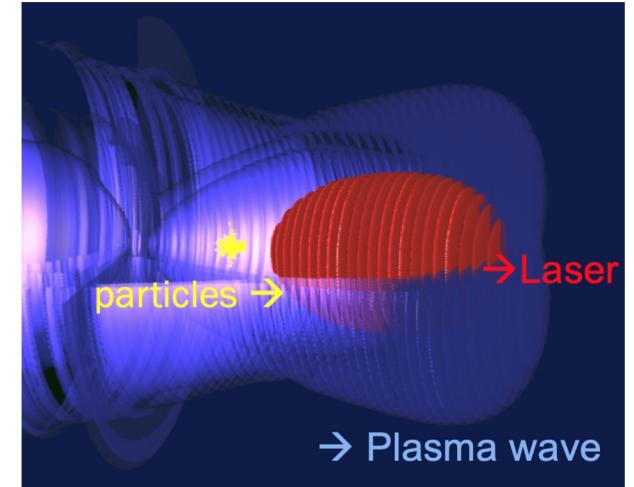


Accelerator Technology and
Applied Physics Division
Cameron Geddes

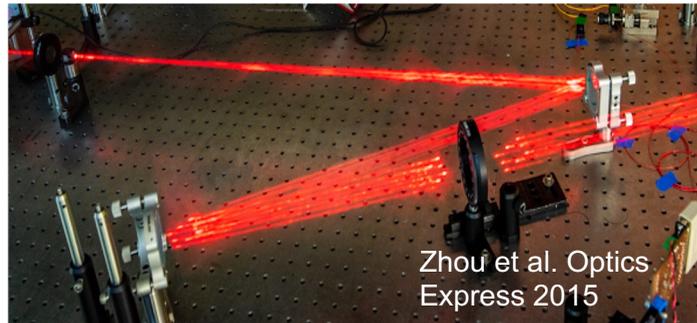
BELLA Center for Laser-Plasma Based Accelerators

- World leading program: 8 GeV energy electrons in just 20 cm
 - would require 100's of m using conventional acceleration techniques
 - competing with \$B scale investments overseas in laser, plasma technologies
- New BELLA 2nd beamline will enable “staging” to higher energies
- Future O(10TeV) collider parameter concepts via ITF and e+e- forum
- Next step: kBELLA will extend to kHz rep rates needed for **future colliders**
 - leverages cross-federal applications: ARDAP, BES, NNSA, FES, DoD...

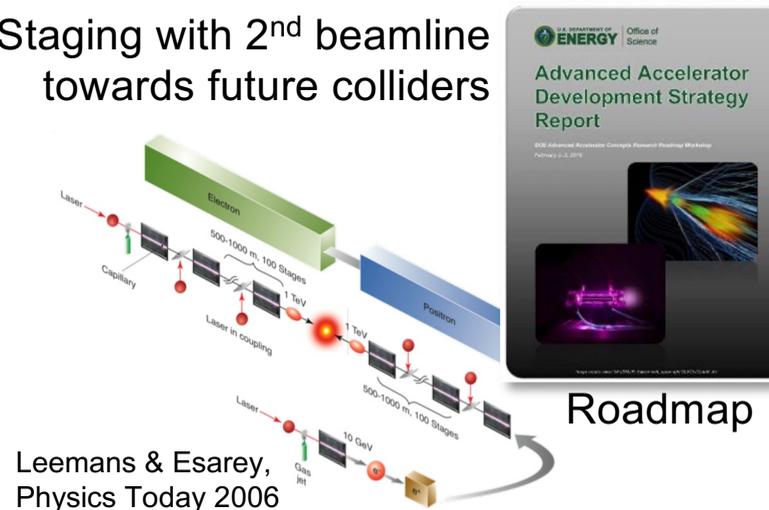
Laser driven plasma wave



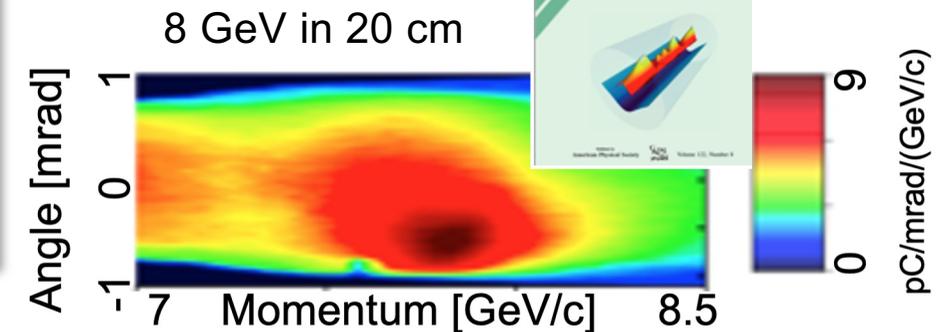
kHz laser technology for colliders
kBELLA & fiber combination



Staging with 2nd beamline
towards future colliders



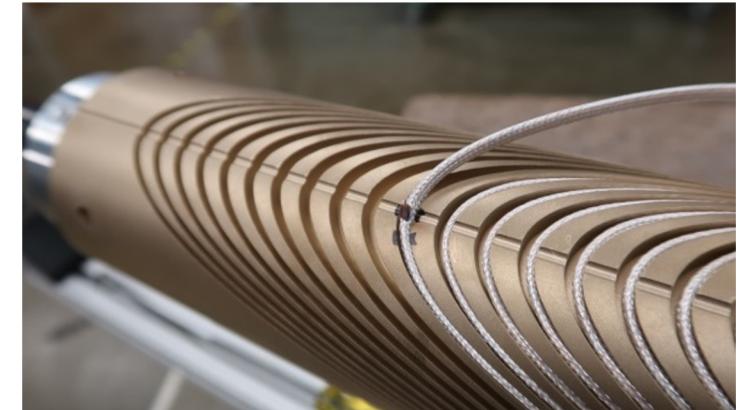
Leemans & Esarey,
Physics Today 2006



LBNL Leads the US Magnet Development Program (US MDP)

- US MDP develops next generation superconducting magnets
 - key to **future circular colliders**, as well as light sources, fusion etc.
- Also playing key roles in High Lumi-LHC Accelerator Upgrade Program for magnet cabling and assembly, to drive increased luminosity
- Exascale accelerator modeling and state of the art active feedback controls and sources enable **intensity & energy frontier accelerators**

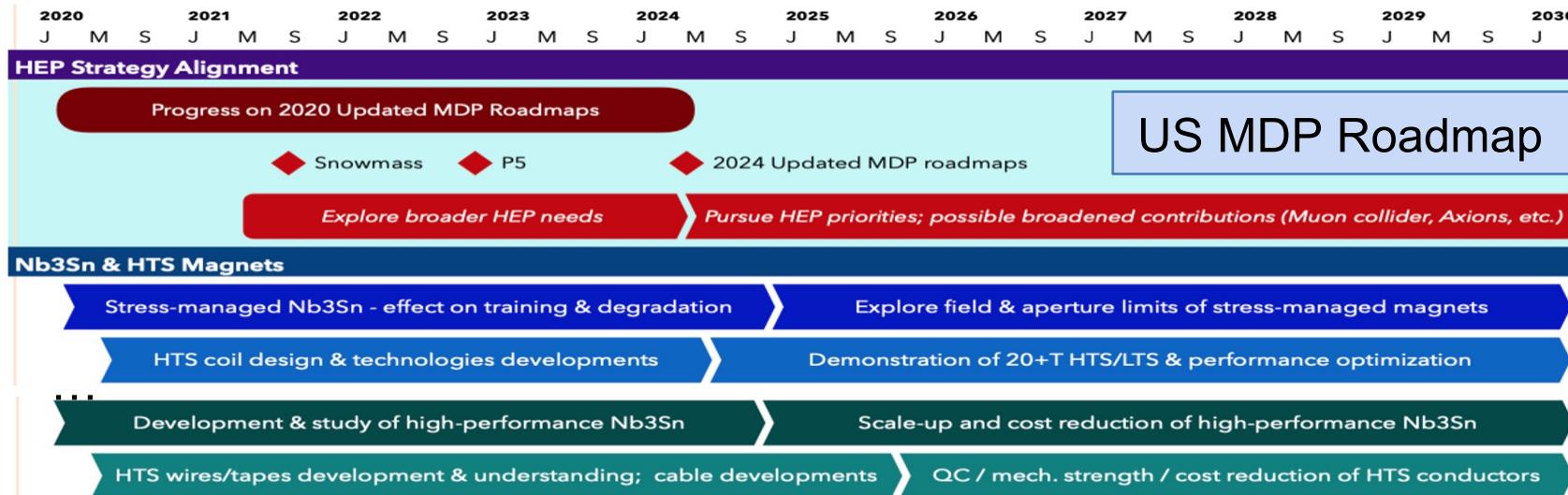
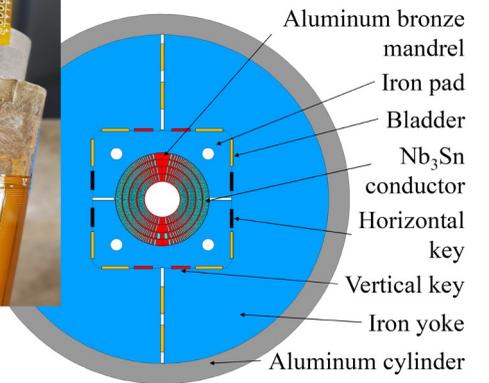
Stress management for high field



High temperature superconductor inserts

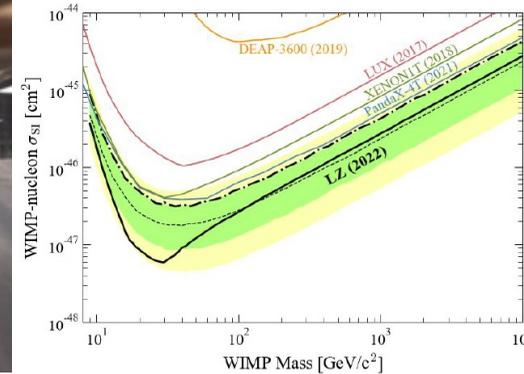
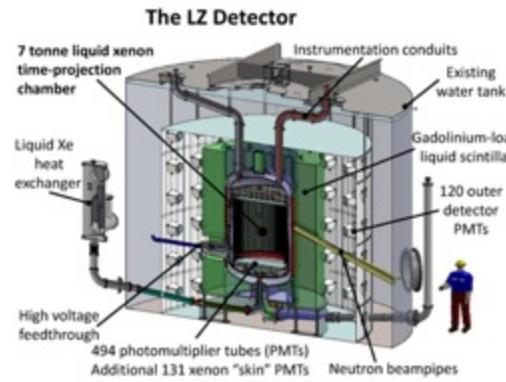


Towards full scale new magnets



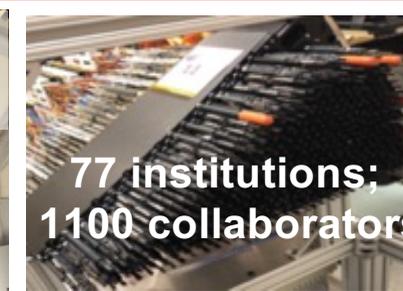
COSMIC FRONTIER @ Berkeley – Leading DM, DE and CMB projects

LZ: 20x increased sensitivity to dark matter

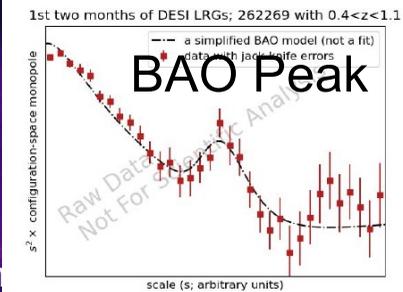


CD-4 awarded in September 2020; First data with world leading results just released!

DESI: 20x increased precision in dark energy, + large scale structure and neutrino masses



Final production petal, with fiber positioners



CD-4 awarded in May 2020; 14 million redshifts observed, more than all previous surveys!

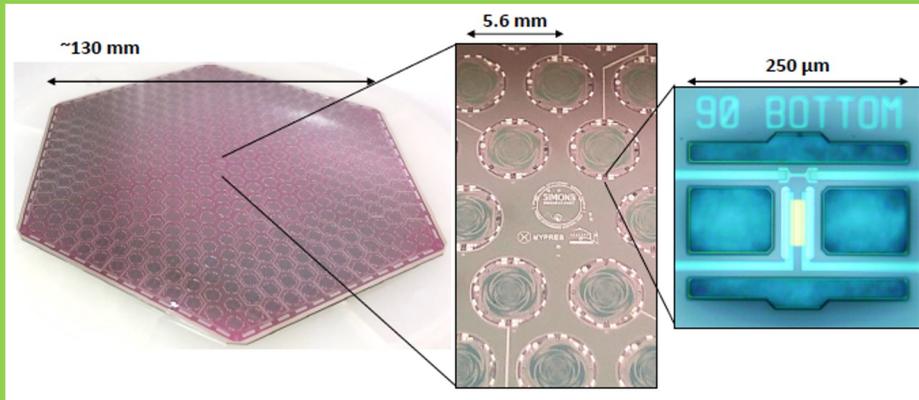
CMB-S4: most sensitive map of the early Universe



CD-0 awarded in 2019; LBNL selected as lead lab in August 2020

Innovations in Instrumentation: ATLAS, DUNE, PIP-II and R&D

Superconducting transition edge detectors for **CMB** and **Dark Matter** experiments;
Technology transfer to industry under SBIR program



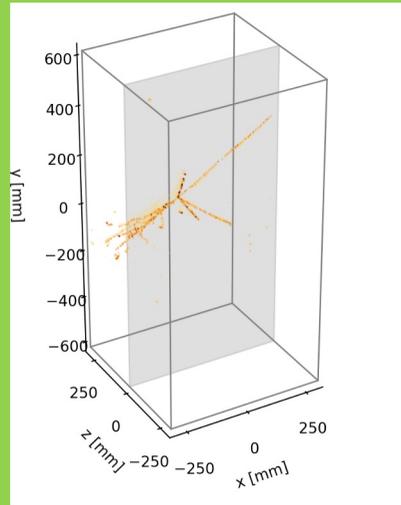
LArPix ASIC bonded to sensor

Cryogenic pixelated readout ASIC (LArPix) for **DUNE**

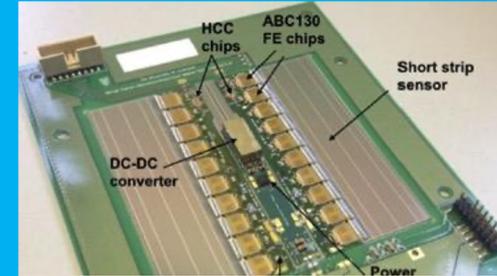
832-channel pixel anode



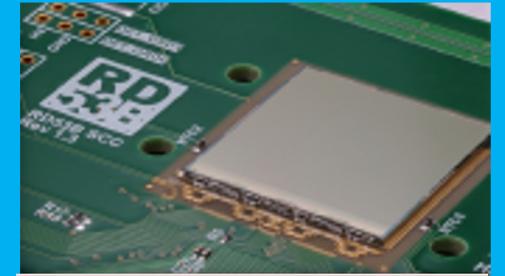
Cosmic Ray Shower imaged with LArPix



Silicon Strip and Pixel detectors for the **ATLAS** experiment at CERN



LBNL design for Silicon Strip barrel module



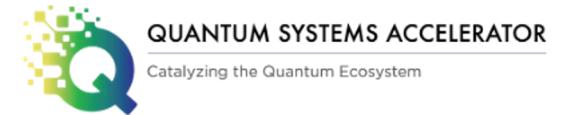
Leadership in pixel readout chip



Scalable controls to extend **accelerators** (**PIP-II**, others) and superconducting qubits by ATAP for AQT

QIS Initiatives: Partnerships

- QIS initiative integrates Physics and ATAP expertise, connections to QSA center
 - Quantum sensor development, quantum computing, qubits and controls
 - Subawards to/from other labs and universities



Advanced Qubit controls



QuantISED Quest



Low-mass Dark Matter;
single phonon detection
with zero dark count

Quantum fields



Table-top gravity

Skipper CCDs QuantISED

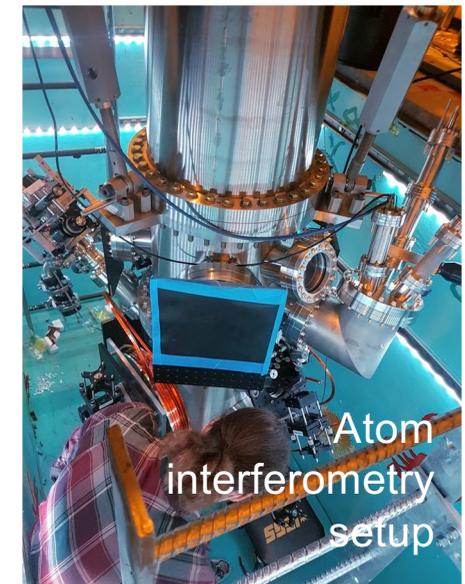


Single photo-electron
read-out

QIS Alpha



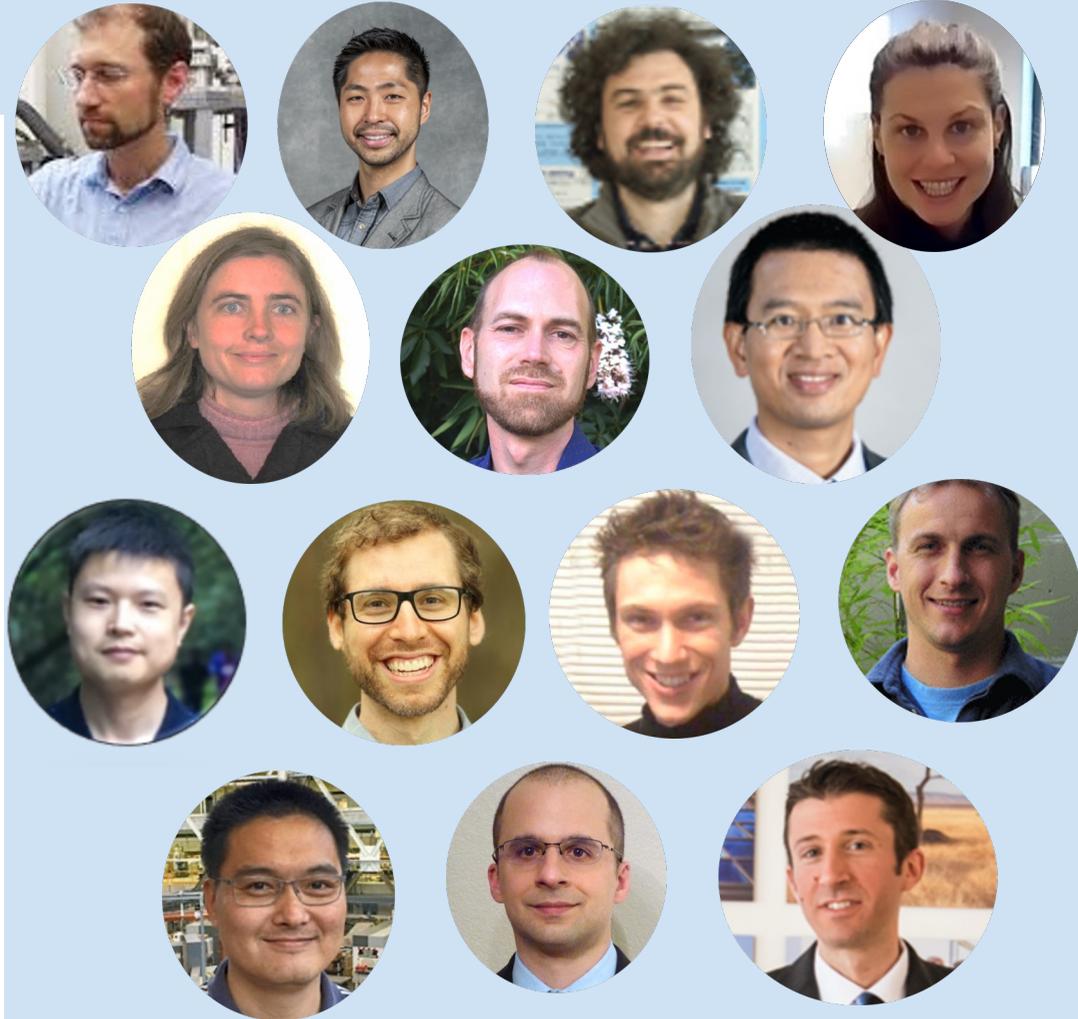
Best-measured
constant



Atom
interferometry
setup

Outstanding Young Scientists – Our Most Important Asset

- 14 recent DOE HEP + BES Early Career Awards =>
- 3 of past 9 recipients of the APS Primakoff Award for early career physicists
- L'Oreal Award for US Woman Scientist in 2021
- European Physical Society Award 2021 for outstanding young particle physicist
- American Phys. Soc. Div. Beams outstanding dissertation 2021



IDEA: Inclusion, Diversity, Equity and Accountability

- [IDEA@Berkeley Lab](#): Fostering a diverse workforce—diverse in experiences, perspectives, and backgrounds—and a culture of inclusion are key to attracting and engaging the brightest minds and advancing our record of scientific excellence and groundbreaking innovations
- [Physical Sciences Area Mentoring Program](#)
 - Launched in 2021 – 50 Mentor/Mentee pairings, who meet monthly for a year
 - Expanded in 2022 to include admin, technical staff – 67 Mentor/Mentee pairings
- Division activities: Quarknet, US Particle Accelerator School, SAGE, Snowmass paper
- Divisional and Area committees, strong participation in professional societies' & reports
- Participation in and executive sponsorship of LBNL Employee Resource Groups
- **Snowmass: CEF participation and climate of field white paper**



Snowmass @ Berkeley Lab

- Snowmass @ LBNL by the numbers:

- 26 Berkeley scientists contributed to Snowmass organization 
- 90 Berkeley scientists co-authored at least 1 Snowmass white paper, total of 104 white papers
- 2 local workshops organized by the Snowmass LBNL cross-cutting steering committee to foster cross-cutting dialog
- 3 Snowmass workshops co-organized/co-hosted by LBNL: “Software and Computing for Small HEP Experiments”, “MultiHEP 2020”, “Advanced accelerators”

Coordination role	Persons
Snowmass Steering Group	1
Frontier Conveners	3
Topical Group Conveners	11
Focused-groups conveners	5
Frontier liaisons	6
Total unique scientists	26

- Snowmass topics of special interest at LBNL:

- CMB-S4: Confirm 2014 P5 Report recommendation
- DESI-2 as a bridge towards a Stage 5 Spectroscopic Survey candidate (MegaMapper)
- G3 Dark Matter experiment – “Dig deep”, eg XLZD
- DMNI – “Prospect wide”, eg TESSERACT, LZ upgrades
- Long-lived particle detection at HL-LHC (eg CODEX)
- AI/ML to discover new physics at HL-LHC
- kBELLA and future laser plasma wave linear accelerators
- Advanced magnets & systems to support future circular colliders and muon collider
- Muon collide detector and reconstruction algorithms

Summary

- LBNL HEP program of discovery science aims to address the most compelling questions in fundamental physics
 - Across the Energy, Intensity and Cosmic frontiers; significant AI/ML and QIS efforts
 - Strengths in advanced accelerators, superconducting magnets, detectors, electronics
 - Outstanding staff, training the next generation
- Team Science is still alive and well at Berkeley – we have strong collaborations with our sister national labs and with universities in all our programs
- We benefit from many resources in the LBNL multi-disciplinary environment
- We aim to forge connections with other DOE SC offices: ASCR, BES, FS, NP
- Berkeley is strongly engaged and supports the Snowmass process towards the next generation of exciting HEP projects